FINAL REPORT

NASA Grant NAG 5-2637 (Rosat)

"Long-Term Monitoring of Active Galactic Nuclei (HRI)"

Rosat Observing Programs

"Intermediate Time Scale Monitoring of the
Broad Line Radio Galaxy 3C390.3"

"Coordinated ASCA and ROSAT Observation of
Temporal and Spectral Variability in Mkn766"

"Long-Term Monitoring of Active Galactic Nuclei"

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This grant covers three Rosat observing programs that were bundled together into one grant at the University of Iowa. These are summarized individually, as follows:

Intermediate Time Scale Monitoring of the Broad Line Radio Galaxy 3C390.3

K. Leighly, R. Edelson et al. (AO5)

The purpose of this investigation was to monitor the broad line radio galaxy 3C 390.3 once every three days for 9.5 months with the ROSAT HRI, in order to characterize the X-ray variability on time scales of days to months. No AGN has ever been subjected to such systematic, even monitoring on these intermediate time scales. The flares and quiescent periods in the light curve suggest that the variability is nonlinear, and a statistical test yields a detection with $\sim 6\sigma$ confidence. Evidence for X-ray reprocessing suggests that the X-ray emission is not from the compact radio jet, and the reduced variability before and after flares suggests there cannot be two components contributing to the X-ray short term variability. Thus, these results cannot be explained easily by simple models for AGN variability, including shot noise which may be associated with flares in disk-corona models or active regions on a rotating disk, because in those models the events are independent and the variability is therefore linear. The character of the variability is similar to that seen in Cygnus X-1, which has been explained by a reservoir or self-organized criticality model. Inherently nonlinear, this model can reproduce a 1/f(1.6–1.8) power spectrum and the reduced variability before and after the large flares. The 3C 390.3 light curve presented here is the first support for such models to explain AGN variability on intermediate time scales from a few days to months.

Coordinated ASCA and ROSAT Observation of Temporal and Spectral Variability in Mkn766

K. Leighly, R. Edelson et al. (AO4)

This project consisted of a 40ks *ASCA* observation of Mrk 766 coordinated with a *ROSAT* PSPC observation of similar length. In the *ASCA* observation we observed rapid variability with a doubling time scale of 1000 seconds. A spectral variability event was observed in which the spectrum softened and hardened above and below $\sim$ 1keV, respectively, as the flux increased. The spectra could be modeled with 5 components: an absorbed power law, warm absorber, iron $K\alpha$ line and soft excess component. The spectral variability resulted from a highly significant change in the intrinsic photon index from $\Gamma \sim 1.6$ to ~ 2.0, an increase in the warm absorber ionization, and a marginally significant decrease in the soft component normalization. A $\sim$ 100eV equivalent width narrow iron $K\alpha$ line was detected in the high state spectrum.

The change in intrinsic photon index and disappearance of the soft excess component in the *ASCA* spectra can be explained as a transition from a first order pair reprocessed spectrum to a pair cascade brought about by a sudden increase in the injected electron

Lorentz factor. The change in the ionization of the warm absorber, though model dependent, could correspond to the increase in flux at the oxygen edges resulting from the spectral index change. This is the first time that such a rapid large change in photon index has been seen.

Long-Term Monitoring of Active Galactic Nuclei

R. Edelson et al. (AO4)

The goal of this project was to characterize the variability properties of a large sample of AGN on time scales of years. Proper measurement required making at least one very short observation every 6 months that the source is accessible to Rosat. Unfortunately, the last two TACs chose to award these targets Priority C under the mistaken belief that most would be done anyway as "filler" observations. This was done in spite of the fact that the proposal clearly spelled out the necessity of Priority B observations. The resulting light curves were not sufficiently well-sampled to permit the proposed temporal and statistical analyses. Because of this, we decided not to propose for later rounds, and the full data set has not been analyzed or published.

Bibliography

High Energy Continuum Variability in Active Galactic Nuclei
R. Edelson 1994, *Proceedings of IAU Colloquium #134: "Multi-Wavelength Continuum Emission of AGN"* (Kulwar), ed. T. J.-L. Courvosier & A. Blecha, 113–123

Long Term Monitoring of Active Galactic Nuclei Using ROSAT
K. Leighly & R. Edelson 1994, BAAS, 184, 59.08

The X-Ray Spectral Variability of Mrk 766
K. Leighly, R. Mushotzky, T. Yaqoob, H. Kunieda & R. Edelson 1996, *ApJ*, **469**, 147.

Results from Monitoring the Broad-Line Radio Galaxy 3C 390.3
K. M. Leighly, et al. 1996, in Proc. "Röntgenstrahlung from the Universe", eds. Zimmermann, H.U., Trümper, J., and Yorke H., 1996, MPE Report 263, 467.

Evidence for Nonlinear Variability from the Broad-Line Radio Galaxy 3C 390.3
K. Leighly & P. T. O'Brien, 1997, *BAAS*, **189**, 3101.

X-ray Observations of the Broad-Line Radio Galaxy 3C 390.3
K. Leighly, P. T. O'Brien, R. Edelson, I. George, M. Malkan, M. Matsuoka, R. Mushotzky, & B. Peterson 1997, *ApJ*, in press.

Evidence for Nonlinear Variability from the Broad-Line Radio Galaxy 3C 390.3
K. Leighly & P. T. O'Brien 1997, *ApJ*, in press.

Steps Toward Determination of the Size and Structure of the Broad-Line Region in Active Galactic Nuclei: Ultraviolet Observations of the Broad-Line Radio Galaxy 3C 390.3
P. O'Brien et al. 1997, *ApJ*, in preperation.